Endogenous Lysine Strategy Profile and Cartel Duration

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Cartel Duration and Endogenous Private Monitoring and Communication: An Instrumental Variables Approach[1]

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Colluding firms often exchange private information and make transfers within the cartels based on the information. Estimating the impact of such collusive practices— known as the "lysine strategy profile (LSP)"— on cartel duration is difficult because of endogeneity and omitted variable bias. I use firms' linguistic differences as an instrumental variable for the LSP in 135 cartels discovered by the European Commission since 1980. The incidence of the LSP is not significantly related to cartel duration. After correction for selectivity in the decision to use the LSP, statistical tests are consistent with a theoretic prediction that the LSP increases cartel duration. *Journal of Economic Literature* Classification Numbers: D43, K21, K42, L13.

Keywords: the lysine strategy profile, post-agreement information exchange, within-cartel transfers, monitoring, verification and promotion of compliance, cartel duration, endogenous covariates

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> "God came down to see what they [the tower builders of Babylon] did and said: 'They ... have one language, and nothing will be withholden from them which they purpose to do.' So God said, 'Come, let us go down and confound their speech.' And so God scattered them upon the face of the Earth, and confused their languages, and they left off building the city ..."
>
> — Genesis 11: 5-8

1. Introduction

A similar design of collusive practices, referred to as the "lysine strategy profile" (hereafter "LSP") by Harrington and Skrzypacz (2011), is frequently observed in recently discovered cartels. The LSP has two components: (1) information sharing and (2) within-cartel transfers. Specially, non-public information that is usually closely guarded by firms in a competitive market, such as sales or customer lists, is assembled and exchanged, providing a basis for assessing deviations to collusive terms; Based on the information, firms make transfers within the cartels; Particularly, firms that oversold compensate firms that undersold. Nearly half of the cartels discovered by the European Commission (hereafter "EC") under its new leniency regime (i.e, after February 19, 2002) had such monitoring and compensation mechanisms in place.[2] 79 percent of international cartels of the 90s sampled by Levenstein and Suslow (2011) exchanged sales information to monitor cheating; One-third agreed upon a within-cartel transfers scheme.[3] Cartel organizational features, such as the LSP, have gained increasing attention from academics and policy makers alike in recent years (e.g., Kühn 2001; Moldovanu 2001; Levenstein and Suslow 2006a, b; Harrington and Skrzypacz 2007, 2011; Vives 2006; Bennett and Collins 2010; OECD 2010). However, little is known empirically about the effect of these features on cartel success. This paper estimates the impact of the particular and often-used organizational feature— the LSP— on cartel duration.[4] The results have implications for design of anti-cartel rules that aim to detect and destabilize cartels through scrutinizing communication and purchases between competitors.

[2] The calculation is based on 57 cartel decisions by the EC for the period February 2002 to April 2011. The result is not reported in the tables.

[3] See Levenstein and Suslow (2011), p. 471.

[4] "Lysine strategy" is defined slightly more broadly in this paper than that in Harrington and Skrzypacz (2011). The precise definition is given in Table 1.

There is a growing body of empirical research that highlights the *association* between cartels' organizational features (such as monitoring and within-cartel transfers) and cartel duration (e.g., Suslow 2005, Zimmerman and Connor 2005, Levenstein and Suslow 2011). However, the existing literature does not adequately address the endogeneity of the features to cartel duration and thus does not convincingly establish a *causal relationship*. Simply put, it is quite likely that "fragile" cartels— cartels that would otherwise be unsustainable— need and create a mechanism of policing and enforcement to prolong their temporary existence. In addition to endogeneity, omitted variables— for example, sectoral demand fluctuations (Suslow 2005; Harrington and Skrzypacz 2011)— may drive both a cartel's duration and its decision regarding whether to adopt an organizational feature, producing misleading estimates on the impact of the feature.[5] For instance, increased demand volatility may lead to both increased complexity in formulating a "cartel contract" and increased difficulty in monitoring the "contract".

This paper proposes an identification strategy for estimating the causal effect of the LSP on cartel duration employing instrumental variable estimation. Specifically, I use exogenous variation in cartel members' national language differences as an instrumental variable for the incidence that a cartel uses the LSP. The number of different national languages is a plausible instrument for the LSP: Communication for monitoring purposes, such as the ones that form the cornerstone of the LSP, is usually undertaken by low-level managers (Levenstein and Suslow 2006a) who may not be multilingual in general.[6] Therefore, linguistic differences pose a sometimes insurmountable barrier to using the LSP. The instrumental variable method makes it credible to assert that the association between the LSP and cartel duration is a causal relationship rather than simply a correlation. As such, this paper is the first to study the endogeneity of cartel organization to cartel success. This is worthwhile because, as will be shown, if the endogeneity of organization is not taken into account, the estimate of its effect will be biased.

The EC discovered cartel data set is an ideal choice for this identification strategy: 81 percent of the cartelized markets involve intermediate goods— so that customers are industrial buyers and thus price and sales are private information between a buyer and a seller (Harrington

[5]Suslow provides empirical evidence that the more uncertain the environment within which a cartel operates, the shorter the expected cartel duration (p. 705). Harrington and Chang show that a cartel lasts longer if the firms earn less profit from cheating.

[6]Levenstein and Suslow (2011) noted that linguistic differences could pose a challenge in cartel cooperation. However, they did not carry out an analysis in this direction. Levenstein and Suslow (2006a) also noted that cartel meetings for monitoring purpose are generally undertaken by low-level managers.

and Skrzypacz 2007, 2011). This creates an incentive for firms to cheat and a potential need for cartels to monitor and promote compliance (through using, for example, the LSP); Moreover, a considerable number of cartels (81) involve firms of different national languages— so that the firms face a potential barrier in exchanging information (and in conditioning transfers on the information). I find that the number of languages is in fact significantly negatively related to the incidence that the LSP is used (in the first-stage regression). However, my identification strategy is inappropriate for other cartel organizational features (such as market-leader arrangement), since linguistic differences are not sufficiently closely linked to those features. Although the analysis is confined to the LSP, it is likely to be of exceptional interest from both the research and policy perspectives, since the incidence of the LSP is high and has increased in the past three decades.[7]

The main empirical findings are as follows. Using a comprehensive data set of EC cartel discoveries over a 30-year span, I find, across a range of regression specifications, that the relationship between cartel duration and the incidence of the LSP is weak and statistically insignificant. In the second main result, I find that the LSP increases cartel duration. The impact is statistically significant, large in magnitude, and robust to various specification and sample choices: Using the LSP, i.e., exchanging private information and making transfers based on the information, decreases the likelihood of cartel dissolution by over seven times.

These results resonate with the recent findings by Harrington and Skrzypacz (2011). They show that colluding firms may use the LSP to sustain collusion in information scarce environments where demand is volatile and price and sales are private information and that the LSP is not needed for organizing collusion if demand is non-stochastic or if prices and sales are commonly observed (p. 8). Moreover, they show that the LSP provides the colluding firms with an incentive to truthfully self-report deviation to and abide by the collusive terms (pp. 10-12).

Admittedly, there are several alternative causal determinants of cartel duration differences, aside from the lysine strategy profile, that could be naturally correlated with firms' linguistic divides. For instance, cartel members' geographic dispersion (Zimmerman and Connor 2005) and cultural cohesion (van Driel 2000; Levenstein and Suslow 2004, 2006a; Zimmerman and

[7]Calculations based on 135 cartel decisions by the EC for the period December 1980 to April 2011 show that 32 percent of the cartels discovered by the EC in 80s used the LSP; Over 40 percent of the discovered cartels in the 90s and 2000s had such collusive practices.

Connor 2005) may affect cartel stability.[8] I attempt to rule out these channels through which linguistic differences may be correlated with cartel duration.

The analysis is subject an important limitation, and the results may best be interpreted with caution. Cartel duration does not fully capture many important aspects of cartel success, such as excess cartel profits or overcharges (Levenstein and Suslow 2006a). But arguably neither marginal costs nor would-be competitive prices are directly observable (Martins *et al.* 1996). The approach adopted here may have advantages to the extent that duration is more directly and cleanly observed (at least in the EC data) and can be more reliably mapped to cartel success (Seventeen and Suslow 2006a, p. 50).

The results may have important policy implications. The debate over the exchange of information between competitors is one of the most controversial in recent years (Capobianco 2004; Levenstein and Suslow 2006b; OECD 2010). Although competition laws in general do not treat information exchange as illegal per se (OECD 2010) and provide no clear guidelines on when antitrust authoerities should enforce law rules against such practices,[9] the data analyzed here indicate that exchange of individual price and sales data with following up inter-firm transfers greatly prolongs the duration of illegal cartels. A tough line on such information exchange seems appropriate.[10]

The paper proceeds as follows. In Section 2, I provide an overview of the literature on the organizational determinants of cartel duration. In Section 3, I describe my data. In Section 4, I present hazard model estimates of the correlation between the LSP and cartel duration. Section 5 presents my main results. Section 6 investigates the robustness of the results. Section 7 concludes.

2. Existing Literature

I am not aware of others who have pointed out the link between linguistic differences and cartel organization, though scholars such as Levenstein and Suslow (2011) have pointed out that

[8]For instance, van Driel (2000) explores the effects of group development in creating a shared culture among firm managers that in turn facilitates collusion. He provides evidence from four European transportation industries that cultural coherence stabilizes a cartel.

[9]An exception is Article 9 of the Mexican Competition Act. The Act explicitly prohibits the "exchange of information" with the object or effect of fixing, increasing or manipulating prices.

[10]Vives (2006) makes a similar statement that the exchange of individual price and quantity data is likely to facilitate collusion and that prohibition aginast such information exchange is desirable, although the impact of such collusive practices on cartel stability is not analyzed formally as in the present paper.

international cartels face unique challenges posed by linguistic differences, among other factors, and that "these factors make international collusion especially difficult to maintain" (p. 457). Nevertheless, Levenstein and Suslow did not establish a link between linguistic differences, cartel organization and cartel duration.

Empirically, my work is related to a number of other attempts to uncover the link between cartel organization and cartel duration, as well to Taylor (2007), who investigates the relationship between cartel organization and cartel success— defined as deviations from competitive outputs. Levenstein and Suslow (2006a) have already provided a detailed review of most of the empirical studies, so I do not attempt to be comprehensive, and instead summarize the main findings of the more relevant and recent studies.

Based on a time-series of mercury cartel activities (1928-1972), MacKie-Mason and Pindyck (1987) argue that organizational issues are not important in determining cartel success. On the opposite side are Zimmerman and Connor (2005) who demonstrate the importance of cartel organization for the duration of international cartels and conclude that further research into this aspect of cartel success remains "a crucial area of consideration in future analysis" (p. 23). Zimmerman and Connor's view is confirmed by Suslow's (2005) findings that the existence of self-imposed penalties has a significant positive relationship with duration and that the more complex a cartel's organization structure, the longer the cartel endures.

Levenstein and Suslow (2006a) highlight the importance of cartel organization, such as trade association involvement or use of joint sales agencies, noting that "although it has not been formally tested, our hypothesis is that the more elaborate these [information] sharing and monitoring mechanisms ... the more stable the cartel" (p. 71). Following Levenstein and Suslow (2006a), a renewed emphasis has been placed on the importance of a cartel's internal underpinnings. Particularly, the authors themselves went on to explore their own hypothesis, using 81 modern-day international cartels (see Levenstein and Suslow 2011). They made a strong case for the relevance of agreed-upon within-cartel transfers scheme and other organizational features (e.g., symmetric punishment) on cartel duration. On the opposite side is work by De (2010) who similarly used the EC data but did not find evidence that within-cartel transfers affected duration (p. 60).

Taylor (2007) studies cartel success, (inversely) defined as "the growth rate of monthly [cartelized] industry output minus the growth rate of ... [an] index of business activity" (p. 608), and confirms most of Suslow (2005)'s findings on the role of organizational factors. Specially,

he finds that agreements with explicit monitoring, quotas, and restrictions on new production capacity were more successful at reducing output under the National Industrial Recovery Act of 1933. He also finds that more complex agreements were more successful.

Some of these authors (Suslow 2005; Levenstein and Suslow 2006a, 2011; Taylor 2007) acknowledge the potential endogeneity problem in estimating the relationship between cartel success and cartels' organization.[11] However, none of the authors have attempted to *formally* address the problem, which is the focus of my paper. The existing analyses may also be prone to omitted variable bias: cartels that exchange private information and conduct transfers may differ from cartels without such collusive practices along many market dimension, some of which are hard to measure, and thus it becomes difficult to pinpoint the true underlying determinants of cartel duration.

My paper is complementary to this growing and lively literature that takes cartels' organizational features as exogenous (or predetermined) and studies their effects on cartel success: Understanding the endogeneity of cartel organizational features (such as the LSP) may help resolve the empirical disputes in this literature that puts the features on the right-hand side of various regressions. Additionally, my paper attemps to correct for one of the potential omitted variabel biases, in particular that in estimating the effect of the LSP.

3. Data

I use data from the complete set of EC cartel decisions between December 17, 1980 to April 13, 2011. The EC data include 143 cartels decided by the EC, the Court of First Instance (CFI) and the European Court of Justice (ECJ). A rich variety of case-specific information is recorded in the data, including the start and end dates of a cartel, the affected product and geographic markets, and the nationalities of the firms.[12] These are the key variables of interest in this paper. My analysis restricts to 135 cartels for which information on cartels' organizational features (such as the LSP) is available. I refer to the 135 cartels as my *full cartel sample*.

Data limitation and remedy. The EC data suffers from a lack of reliable information on producer concentration. The variable has been shown to be an important determinant of cartel

[11] Levenstein and Suslow (2006a), for instance, note that "[cartel] organization is ... not an exogenous variable". See Levenstein and Suslow (2006a), p. 74.

[12] Unless otherwise specified, all euro values throughout the paper are adjusted to 2010 € using standard measure of general price trends published by the OECD on the Producer Price Indices for prices, labor costs and interest rates of domestic manufacturing.

stability (Selten 1973) and could be correlated with a cartel's decision to monitor cheating. Omission of this variable could well bias some of the estimated effects of leniency and those of other predictors in my empirical analysis. In some cases, the EC reports market shares of cartel participants near the end of an infringement. However, using the information (e.g., De 2010) may give rise to endogeneity problems: Existing market shares may be results of cartel activities in deterring entries (Harrington 1989; Seventeen and Suslow 2011). Therefore, market concentration may increase as collusion advances; Alternatively, the market shares of a cartel may decrease over its lifetime if collusive profits attract more (non-conspiring) entrants into the market in question than would be in a more competitive environment (Sutton 1991, 1998; Symeonidis 2002; and Levenstein and Suslow 2010). To remedy at least in part the potential model misspecification bias, I include, as do Levenstein and Suslow (2011), the total number of participating cartelists as a crude measure of producer concentration. Although old participants may exit and new firms may join force in mid of an infringement, the total number of participated firms is invariant to the duration of the infringement.

Cartel duration. The main variables and model parameters are defined in Table 1, and the corresponding descriptive statistics are presented in Tables 2. Column 1 of Table 2 gives descriptive statistics for the full cartel sample. The remaining columns give descriptive statistics for groups of cartels at different quartiles of the number of languages of a cartel. This is useful because the number of language is my instrument for the LSP.

Besides reporting proven start dates of agreements, the EC sometimes reports suspected start dates without support of documented evidence. Unless stated otherwise, throughout the paper I refer, as do Levenstein and Suslow (2011), to the *start date of an agreement* as its proven start date. Moreover, firms may participate in and leave a cartel at different dates; collusive agreements sometimes start in one region then spread over many regions (Levenstein and Suslow 2011). I refer, as do the EC, the CFI and Levenstein and Suslow (2011),[13] to DURATION as the number of months elapsed from the proven start date of the first agreement

[13]In various judgments, the Court of First Instance made it clear that it was not necessary, particularly in the case of a complex infringement of considerable duration, for the EC to characterize it as exclusively an agreement or concerted practice, or to split it up into separate infringements. See, e.g., OJ [1999] L 76/1, [1999] 4 CMLR 1316, on appeal Cases T-202/98 etc Tate & Lyle v Commission (judgment pending), para 70. See also 9 OJ [1994] L 243/1, [1994] 5 CMLR 547, para 128 and OJ [1999] L 24/1, [1999] 5 CMLR 402, paras 131-132, on appeal Cases T-9/99 etc HFB Holding v Commission (judgment pending).

Table 1. Terms and Definitions of Main Variables

	Definition
Cartel	An agreement or a series of agreements between competing firms or associations of firms that constitutes a single infringement, according to the EC, of Art. 101 (formerly Art. 81 and Art. 85) of the EC treaty.
Start date	Start date of the first agreement between any two participants of a cartel.
End date	Known ending date of the last agreement(s) between any two cartel participants for cartels ended prior to a detection. For cartels ended due to a detection, it is set as the date of the EC's decision.
	A. Cartel Durability Measures
DURATION	The number of months between a cartel's start and end dates that is proven by documented evidence.
DURATION-2	The greater of [1] the number of months elapsed between a cartel's start and end dates that is suspected by the EC but without documented evidence; and [2] DURATION.
	B. Linguistic Differences Measure
LANG	Number of different national languages of the cartel members.
	C. Cartel Organizational Features
LYSINE	1 if cartel monitors the agreement(s) by having firms report sales, price, market share or customers and conditions within-cartel transfers (money or inter-firm sales) on those reports; 0 otherwise.
MARKET-ALLOC	1 if members of a cartel agreed to allocate specific customers or types of customers, products, or territories among themselves; 0 otherwise.
TRADE-ASSO	1 if a trade association is actively involved in facilitating collusion; 0 otherwise.
MARKET-LDR	1 if one or more members took the role of a price or market leader; 0 otherwise.
RETALIATION	1 if retaliatory action was taken following cheating; 0 otherwise.
	D. Antitrust Policies
LENIENCY	0 if a cartel ends before July 18, 1996; 1 if it ends after July 18, 1996, but before February 19, 2002; 2 if it ends after February 19, 2002.
FINES	The total corporate cartel fines per infringement issued by the EC during the previous fiscal year.
	E. Market Structure
FIRMS	The total number of competitors in a cartel.
INDUSTRY TYPE	Categorical variable indicating the type of industry where a cartel operates. The industry types are wholesale and retail trade; food, feed and tobacco; chemicals; transport; primary material; machinery, equipment and metal products; and other products and services.
MARKET SCOPE	Categorical variable indicating the scope of the geographic market. The scopes are national, multinational (but less then EU-wide), EEA-wide or EU-wide, and worldwide..

(*continued overleaf*)

TABLE 1. (*Continued*)

	Definition
	F. Macroeconomic Fluctuations
Δ GDP	Annual growth rate of the real domestic product of the relevant geographic market. If the relevant geographic market consisted of multiple economic areas in multiple countries, it is the weighted average of the growth rates. The weight applied is the annual national GDP.
PEAK-TROUGH	1 if a cartel ended during a peak-to-trough period of a business circle; 0 otherwise. If the relevant geographic market consisted of multiple economic areas in multiple countries, it is the weighted average of the indicators. The weight applied is the annual national GDP.
INTEREST	Annual average short-term interest rates, 3-month maturity. If the relevant geographic market consisted of multiple economic areas in multiple countries, it is the weighted average of the short-term rates. The weight applied is the annual national GDP.
POS-SHOCK	Positive deviation of real annual GDP from trend line (using the Hodrick-Prescott filter). If the relevant geographic market consisted of multiple economic areas in multiple countries, it is the weighted average of the deviations. The weight applied is the annual national GDP.
NEG-SHOCK	Negative deviation of real annual GDP from trend line (using the Hodrick-Prescott filter). If the relevant geographic market consisted of multiple economic areas in multiple countries, it is the weighted average of the deviations. The weight applied is the annual national GDP.

to the end date of the last agreement between any two participants of a cartel. In robustness checks, I obtain similar results using suspected durations.

The average DURATION (DURATION-2) of cartels in my sample is approximately 96.6 months (resp. 105.4 months). This is comparable with the average duration of international cartels reported by Levenstein and Suslow (2011) (approx. 97.2 months) and that of pre-World War II European cartels (approx. 99.6 months) reported by Suslow (2005). There are large differences in duration across the sampled cartels in terms of both proven and suspected duration, and the standard deviation of DURATION and DURATION-2 are 89.3 and 99.2 months, respectively.

Cartel Organizational Features. I use a variety of variables to capture the differences in cartels' organization. My main variable, LYSINE, indicates whether a cartel uses the lysine

Table 2: Descriptive Statistics

Panel A. Cartel Duration, Organizational Features, Antitrust Policies, Market Concentration and Macroeconomic Fluctuations

		By quartile of LANG			
	full cartel sample	(1)	(2)	(3)	(4)
	Cartel Durability Measures				
DURATION	96.57 (89.25)	96	129	58	73
DURATION-2	105.36 (99.21)	110	136	58	77
Levenstein and Suslow (2011)	97.2 (69.6)				
Suslow (2005)	99.6 (74.4)				
	Cartel Organizational Features				
LYSINE (1=yes)	0.41 (0.49)	0.47	0.41	0.30	0.36
MARKET-ALLOC (1=yes)	0.72 (0.45)	0.76	0.68	0.5	0.76
RETALIATION (1=yes)	0.30 (0.46)	0.25	0.22	0.6	0.39
TRADE-ASSO (1=yes)	0.53 (0.50)	0.55	0.49	0.6	0.52
MARKET-LDR (1=yes)	0.46 (0.50)	0.51	0.38	0.3	0.52
	Antitrust Policies				
LENIENCY	0.74 (0.80)	0.78	0.78	0.3	0.76
FINES (€ mln.)	453 (804)	418	528	308	473
	Market Structure and Macroeconomic Fluctuations				
FIRMS	450 (4, 201)	903	223	14	82
INTEREST (%)	6.06 (3.56)	5.42	6.58	9.47	5.49
PEAK-TROUGH (1=yes)	0.54 (0.47)	0.53	0.54	0.40	0.60
ΔGDP (%)	2.39 (1.57)	2.35	2.52	2.19	2.36
POS-SHOCK (€ bln.)	25,336 (64, 840)	18,956	28,886	6,064	37,829
NEG-SHOCK (€ bln.)	30,988 (56, 871)	39,317	26,477	19,052	25,781
Observations	135	55	37	10	33

SOURCE.– Author's calculations based on 135 cartel decisions by the European Commission and judgments of the Court of First Instance and the European Court of Justice for the period December 1980 to April 2011.

NOTE.– Standard deviations are in parenthesis. Quartiles of LANG are: (1) one langauge; (2) two languages; (3) three languages; (4) four or more different languages.

strategy profile. It equals one if cartel members exchanged information on sales, prices, customers or market shares for monitoring purposes and conditioned monetary transfers or inter-firms sales on the information.

Various other cartel organizational features are considered— including market allocation scheme, involvement of a trade association, market leader arrangement and retaliation. They control for factors that are correlated with both the LSP and cartel duration that are not captured by the other variables. Levenstein and Suslow (2011), for example, show that market allocation may reduce the likelihood that a cartel is detected and at the same time reduces the need to create monitoring mechanisms.[14] Admittedly, some of these features are also potentially

[14]Levenstein and Suslow (2011), p. 475 and p.479.

Table 2: Descriptive Statistics

Panel B. Industry Type and Market Scope

		By quartile of LANG			
	full cartel sample	(1)	(2)	(3)	(4)
	INDUSTRY TYPE				
Wholesale & retail trade	5 (3.7%)	1	1	1	2
Food, feed & tobacco	10 (7.4%)	2	2	1	5
Primary material	19 (14.1%)	4	8	6	1
Chemicals	41 (30.4%)	16	13	0	12
Mach., equip. & metal products	24 (17.8%)	13	5	1	5
Transport	15 (11.1%)	11	2	1	1
Other products & services	21 (15.6%)	8	6	0	7
	MARKET SCOPE				
National	36 (26.7%)	11	9	5	11
Multinational	17 (12.6 %)	8	5	2	2
EEA-wide or EU-wide	59 (43.7 %)	26	18	3	12
Worldwide	23 (17%)	10	5	0	8
Observations	135	55	37	10	33

SOURCE.– Author's calculations based on 135 cartel decisions by the European Commission and judgments of the Court of First Instance and the European Court of Justice for the period December 1980 to April 2011.

NOTE.– The panel reports the number of observations in each industry and market scope category, respectively. Percentages are in parenthesis. Quartiles of LANG are: (1) one langauge; (2) two different languages; (3) three different languages; (4) four or more different languages.

endogenous variables. For instance, cartels that have to punish their members may suffer from fundamental disagreements over how to set prices or divide markets (Levenstein and Suslow 2011, p. 485) and be otherwise unsustainable without retaliatory measures. However, like previous contributors to this literature, I am severely hampered by the absence of reliable instruments for these potential endogenous variables. Investigating and controlling for the potential endogeneity of these organizational features are beyond the scope the present study.

Antitrust policies. A second set of variables captures aspects of the institutional environment where cartels form and dissolve. LENIENCY equals zero if a cartel dissolved before July 18, 1996, i.e., before a leniency regime was introduced in the EU; it equals one if the cartel failed after July 18, 1996 but before February 19, 2002, i.e., the period during which the 1996 Leniency Notice was in effect; it equals two if the cartel broke up after February 19, 2002, i.e., after the existing leniency regime replaced the 1996 regime. A second institution variable, FINES, controls for the severity of punishment. Similar to that in Miller (2009), the penalty variable is defined as the total corporate fines issued by the EC during the previous fiscal year.[15]

[15]Using the average corporate fines per cartel during the previous year does not alter the results significantly.

Market Structure and Macroeconomic Fluctuations. The next two sets of variables reflect the possible variations in the market and macroeconomic environments where cartels operate. Some of these variables control for, at least in part, the potential heterogeneity in dissolution probabilities across cartels. These variables have been used in previous analysis of cartel duration (Zimmerman and Connor 2005; Suslow 2005; Levenstein and Suslow 2011). I do not describe these well-known variables in detail here, and instead refer the reader to the excellent variable description in Levenstien and Suslow's and Zimmerman and Connor's articles. Summary statistics of these variables are reported in the final rows of Panel A of Table 2 and Panel B of the table.

4. The LSP and Cartel Duration: Simple Hazard Model Estimates

The regression analysis begins with a "naïve" hazard model where I specify dissolution hazard— the probability of cartel dissolution conditional on cartel not having already collapsed— as a function of LYSINE and the other explanatory variables. In this way, the model ignores the potential endogeneity of the LSP. In what follows, I discuss two alternative empirical specifications. The second specification is a generalization of the first.

■ **Cox's (1972) semiparametric proportional hazard model** is the most popular approach towards characterizing the hazard function $h(t;\cdot)$. The model has been used in previous analysis of cartel durations (e.g., Suslow 2005; Zimmerman and Connor 2005; Levenstein and Suslow 2011; Zhou 2011) and is flexible enough to account for potential inappropriate distribution assumptions that may be involved in parametric methods.[16] The hazard function for cartel i is

$$h_i(t;\text{LYSINE}_i,\mathbf{x}_i) = h_0(t) \times \exp(\text{LYSINE}_i\,\beta_{\text{LYSINE}} + \mathbf{x}_i'\beta_{\mathbf{x}}) \tag{1}$$

where t is the elapsed time since the start date of a cartel, LYSINE_i is the dummy variable indicating whether cartel i uses the LSP and $\mathbf{x}_i$ is a vector of other explanatory variables listed in Table 1. β_{LYSINE} (resp. $\beta_{\mathbf{x}}$) is the coefficient (resp. vector of coefficients) associated with the use of the LSP (resp. the other explanatory variables), measuring the correlation between the strategy (resp. the other explanatory variables) with the dissolution hazard. The term "$\text{LYSINE}_i\,\beta_{\text{LYSINE}} + \mathbf{x}_i'\beta_{\mathbf{x}}$" shifts the baseline hazard function $h_0(t)$, and a positive coefficient

[16] The advantages of using Cox (1972) model to analyze time to event data have been widely recognized. See, e.g., Kalbfleisch and Prentice (1980), Meyer (1990), and Perperoglou (2005).

indicates that the observed characteristics are positively correlated with the dissolution hazard and negatively correlated with the cartel duration. The model is semiparametric in that the baseline hazard $h_0(t)$ is a nonparametric function of time, without the influence of the observable characteristics specified assuming a particular functional form. I refer to the model as my *basic regression model*.

Suppose that there are n observations and k distinct cartel dissolution times. Further suppose that I can rank the dissolution times such that $t_1 < t_2 < ... < t_k$ where t_j denotes the dissolution time for the jth cartel. Furthermore, let R_j denote the set of cartels that have not dissolved until time t_j. Then the probability that the m-th cartel will dissolve at time t_j given that some cartel in set R_j will collapse at time t_j is

$$\frac{h_m(t_j; \text{LYSINE}_m, \mathbf{x}_m)}{\sum_{\tau \in R_j} h_\tau(t_j; \text{LYSINE}_\tau, \mathbf{x}_\tau)} = \frac{\exp(\text{LYSINE}_m \beta_{\text{LYSINE}} + \mathbf{x}_m' \beta_{\mathbf{x}})}{\sum_{\tau \in R_j} \exp(\text{LYSINE}_\tau \beta_{\text{LYSINE}} + \mathbf{x}_\tau' \beta_{\mathbf{x}})}. \tag{2}$$

Taking the product of the conditional probabilities in (2) yields the partial likelihood function

$$\mathcal{L} = \prod_j \left[\frac{\exp(\text{LYSINE}_j \beta_{\text{LYSINE}} + \mathbf{x}_j' \beta_{\mathbf{x}})}{\sum_{\tau \in R_j} \exp(\text{LYSINE}_\tau \beta_{\text{LYSINE}} + \mathbf{x}_\tau' \beta_{\mathbf{x}})} \right],$$

with corresponding log-likelihood function

$$\ln \mathcal{L} = \sum_j \left[\text{LYSINE}_j \beta_{\text{LYSINE}} + \mathbf{x}_j' \beta_{\mathbf{x}} - \ln \sum_{\tau \in R_j} \exp(\text{LYSINE}_\tau \beta_{\text{LYSINE}} + \mathbf{x}_\tau' \beta_{\mathbf{x}}) \right]. \tag{3}$$

■ **Competing risks.** A cartel can end for different causes: Besides "natural death" such as defection, independent discoveries by an antitrust prosecutor can also terminate a cartel. Therefore, estimation of the cartel dissolution hazard function from observed cartel durations must also consider the censoring of duration for cartels ending due to antitrust interventions (Levenstein and Suslow 2011). For such cartels, we can only infer that collusion would have exceeded the observed cartel duration at the time of the cartel's dissolution.

A popular choice towards the analysis of competition risks is using a stratified Cox model from augmented data (Lunn and McNeil 1995). Let ϕ denote a cartel's *failure type* where $\phi = 0$ indicates those cartels collapsed in a natural death; $\phi = 1$ indicates those cartels that ended in an antitrust intervention. The joint distribution of failure times and cause of failure is considered and the hazard function of a particular cause in the presence of all other causes is estimated. In the absence of ties (i.e., multiple cartel groups fail at the same t_j) the full partial

log-likelihood is given by

$$\ln \mathcal{L} = \sum_{j,\,\phi_j=0} \left(\text{LYSINE}_j \beta_{\text{LYSINE}} + \mathbf{x}_j' \beta_{\mathbf{x}}\right) + \sum_{j,\,\phi_j=1} \left(\beta_0 + \text{LYSINE}_j \beta_{\text{LYSINE}} + \mathbf{x}_j' \beta_{\mathbf{x}}\right) - \sum_j \ln \left[\sum_{\tau \in R_j} \left(\exp\left(\text{LYSINE}_\tau \beta_{\text{LYSINE}} + \mathbf{x}_\tau' \beta_{\mathbf{x}}\right) + \exp\left(\beta_0 + \text{LYSINE}_\tau \beta_{\text{LYSINE}} + \mathbf{x}_\tau' \beta_{\mathbf{x}}\right)\right)\right] \quad (4)$$

where β_0 is a constant so that the baseline hazard functions for different types of cartel dissolution differ by a constant ratio.

Running standard Cox regression on the augmented data set gives the appropriate estimates of the regression coefficients, provided the model fit it good. The partial likelihood which results from the method is precisely the partial likelihood suggested by Kalbfleisch and Prentice (1980) for competing risks.

Table 3 reports the Cox regression estimates of the coefficients. Unless otherwise stated, the coefficient of interest throughout the paper is that of the LSP, the effect of the lysine strategy profile on cartel duration.

Column (1) shows that in the full cartel sample there is a negative but statistically insignificant correlation between the LSP and cartel duration. Figure 1 shows this relationship diagrammatically. In Column (2), I add market conditions as regressors (I follow the literature to use the number of colluding firms, the industrial sectors and the geographic market scope). This changes the coefficient of the LSP little. Columns (3)-(4) show that the correlation between the LSP and cartel duration is quite similar to that in (1) and (2) with controls for changes in macroeconomic conditions (column (3)) and the effects of antitrust policies (column (4)).

In column (5), I add dummies for other cartel organizational features. As discussed in the previous section, including these features may give rise to endogeneity concerns. The main point here is that the weak and statistically insignificant correlation between the LSP and cartel duration is unaffected by the inclusion of these variables as additional controls in the specification. Finally, column (6) includes all the exogenous covariates and LYSINE, but excludes the other cartel organizational features; column (7) adds all the variables in this table simultaneously. Again, these controls have very little effect on my main estimate.

Overall, the results in Table 3 show a weak correlation between the lysine strategy profile and cartel duration. These results largely resemble those of a previous stduy (De 2010) that is

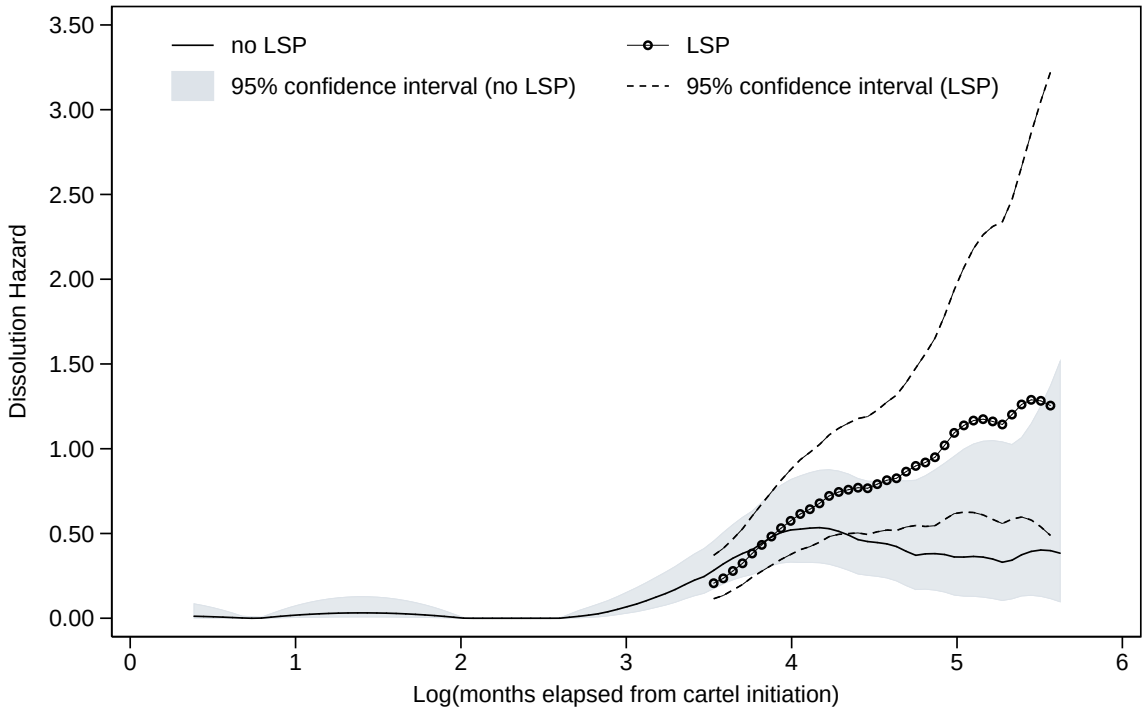

FIGURE 1. CARTEL DISSOLUTION HAZARD BY GOVERNANCE AND COMPENSATION SYSTEM

Notes: The sample consists 135 cartels decided by the EC, the CFI and the ECJ between December 17, 1980 to April 13, 2011. The circled line corresponds to cartels that use the lysine strategy profile with the dashed line indicating the 95% confidence interval. The solid line corresponds to cartels without the lysine strategy profile with the shaded area indicating the 95% confidence interval.

based on a time series of cartel discoveries by the EC for the years 1990-2008.[17] However, there are two important reasons for not interpreting this weak relationship as a lack of strong causal effect. First, weak cartels— cartels that would otherwise be unsustainable or short-lived— may need and choose the LSP. Arguably, more important than this reverse causality problem, there are many omitted determinants of cartel duration differences that will naturally be correlated with a cartel's choice regarding its organizational mechanisms, such as the LSP. These problems introduce negative bias in the estimates of the effect of the LSP on cartel duration. Both problems could be solved if we had an instrument for the LSP. Such an instrument must be an important factor in accounting for the variation in the choices regarding the LSP, but have no direct effect on cartel duration. The discussion to follow proposes an identification strategy that uses cartel members' linguistic differences as an instrument.

[17]See the online appendix for an analysis using the 1990-2008 data of EC cartel discoveries. Unfortunately, I do not have access to the data used by the other authors to test for the existence of endogeneity in these datasets.

Table 3. The Lysine Strategy Profile and Cartel Duration (Cox Hazard Model Estimates)

	Dependent Variable Is Log(DURATION+1)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LYSINE	0.16	0.03	0.11	0.05	−0.18	0.06	−0.14
	(0.24)	(0.27)	(0.29)	(0.28)	(0.30)	(0.31)	(0.37)
Log(FIRMS)		−0.31**	−0.38***	−0.34**	−0.39***	−0.39***	−0.44***
		(0.12)	(0.11)	(0.13)	(0.15)	(0.12)	(0.16)
Food, feed & tobacco		−1.02	−1.53*	−1.15	−1.27	−1.76**	−2.29**
		(0.75)	(0.81)	(0.81)	(0.79)	(0.85)	(0.95)
Primary material		−0.82	−1.13	−0.93	−1.28	−0.85	−1.84**
		(0.77)	(0.70)	(0.81)	(0.84)	(0.66)	(0.87)
Chemicals		−0.89	−1.22*	−0.98	−1.23*	−1.23**	−2.03**
		(0.68)	(0.69)	(0.73)	(0.74)	(0.62)	(0.80)
Machinery, equipment &		−1.08	−1.45**	−1.21	−1.40*	−1.53**	−2.28***
metal products		(0.69)	(0.71)	(0.75)	(0.78)	(0.68)	(0.84)
Transport		−1.43	−1.76*	−1.64*	−1.88*	−1.87**	−2.61**
		(0.91)	(0.90)	(0.98)	(1.08)	(0.95)	(1.15)
Other products & services		−0.76	−1.07	−0.82	−0.91	−1.20	−1.71**
		(0.73)	(0.75)	(0.76)	(0.81)	(0.74)	(0.86)
Multinational		0.15	0.05	0.24	0.02	0.02	0.06
		(0.70)	(0.67)	(0.70)	(0.71)	(0.71)	(0.78)
EEA-wide or EU-wide		0.16	0.13	0.23	0.13	−0.22	−0.02
		(0.48)	(0.49)	(0.48)	(0.46)	(0.56)	(0.61)
Worldwide		0.56	0.55	0.62	0.62	−0.07	0.23
		(0.48)	(0.62)	(0.49)	(0.48)	(0.76)	(0.88)
Log(INTEREST)			0.29			−0.12	0.09
			(0.29)			(0.83)	(0.87)
Log(PEAK-TROUGH+1)			0.31			0.41	0.02
			(0.36)			(0.37)	(0.41)
Log(Δ GDP+2)			−0.44**			−0.57***	−0.60***
			(0.19)			(0.19)	(0.20)
Log(POS-SHOCK)			−0.05			0.06	0.02
			(0.11)			(0.13)	(0.15)
Log(NEG-SHOCK)			0.02			0.14	0.11
			(0.11)			(0.14)	(0.15)
EC's 1996 Leniency				−0.31		−0.20	−0.04
				(0.28)		(0.60)	(0.66)
EC's 2002 Leniency				−0.34		−1.27	−1.11
				(0.46)		(0.91)	(0.99)
Log(FINES)				0.01		0.10	0.09
				(0.05)		(0.07)	(0.07)
MARKET-ALLOC					−0.72*		−0.71*
					(0.37)		(0.42)
RETALIATION					0.37		0.54
					(0.30)		(0.34)

(*continued overleaf*)

TABLE 3. (*Continued*)

	Dependent Variable Is Log(DURATION+1)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
TRADE-ASSO					−0.20		−0.38
					(0.27)		(0.33)
MARKET-LDR					0.83***		0.79**
					(0.32)		(0.36)
Observations	135	135	135	135	135	135	135
Number of failures	72	72	72	72	72	72	72
Time at risk	571.003	571.003	571.003	571.003	571.003	571.003	571.003
Log-pseudo likelihood	-292.32	-284.82	-278.81	-284.23	-278.83	-276.76	-271.02

NOTE.– All regressions are Cox proportional hazard models with competing risks. Robust standard errors are in parentheses. All euro values are in 2010 €. Omitted industry category is "wholesale and retail trade". Omitted market scope category is "national market". Omitted LENIENCY category is "no leniency". The source for these values is author's calculations based on 135 cartel decisions by the EC between 1980 and April 2011. *** significant at 1 percent level. ** significant at 5 percent level. * significant at 10 percent level.

5. The LSP and Cartel Duration: Two Stage Residual Inclusion Instrumental Variable Results

5.1. *Estimation Framework*

Owning to the inherent nonlinearity of the hazard models, attempting to correct for endogeneity bias via application of the conventional two-stage least squares (2SLS) methods will be susceptible to bias (Terza, Bradford and Dismuke 2008). To address the problem, I implement the two-stage residual inclusion (2SRI) estimator as suggested by Terza, Basu and Rathouz (2008). The 2SRI approach is a nonlinear extension of the conventional 2SLS method. The approach can provide unbiased and consistent estimates when analyzing hazard models in the event of endogenous explanatory variables (Terza, Basu and Rathouz 2008).

I consider the number of different national languages of cartel members to be a good candidate instrument based on the fact that monitoring contacts are usually undertaken by low-level managers who may not be multilingual in general. Linguistic difference therefore poses a sometimes insurmountable barrier to monitoring—the key component of the LSP. Moreover, there is no theoretic reason to believe that the number of languages should affect cartel durability except through the intermediation of the choice for the LSP.

My 2SRI model has two stages. In the first-stage, I regress the potentially endogenous choice of the LSP— LYSINE— on the vector exogenous variables ($\mathbf{x}^{\text{LYSINE}}$) and the instrumental

variable (LANG):

$$\text{LYSINE}_i = \mathbf{x}_i^{\text{LYSINE}} \alpha_{\mathbf{x}} + \text{LANG}_i \alpha_{\text{LANG}} + \omega_i \tag{5}$$

where $\mathbf{x}^{\text{LYSINE}}$ is a subset of $\mathbf{x}$, the "α's" are the coefficient parameters to be estimated and ω_i denotes the random regression error term. The parameters of equation (5) are estimated using a probit model and the residuals ($\hat{\omega}_i$'s) are saved.

A second-stage regression is then estimated for the cartel dissolution hazard that includes the first-stage residuals as an additional explanatory variable in the regression equation together with the other explanatory variables used in equation (1):

$$h_i(t; \text{LYSINE}_i, \mathbf{x}_i, \hat{\omega}_i) = h_0(t) \times \exp(\text{LYSINE}_i \gamma_{\text{LYSINE}} + \mathbf{x}_i' \gamma_{\mathbf{x}} + \hat{\omega}_i \gamma_{\omega}) \tag{6}$$

where the "γ's" are the coefficient parameters to be estimated. The residuals serve two roles in equation (6). First, they control for potential endogeneity of the LSP. Second, their inclusion provides a simple diagnostic tool to statistically test for endogeneity of LYSINE: If γ_{ω} is statistically significant in equation (6), then LYSINE is endogenous; If, on the other hand, γ_{ω} is insignificant, then LYSINE is considered exogenous and, consequently, the "naïve" model defined in equation (1) is preferred on efficiency grounds.

The full partial log-likelihood function for the two-stage residual inclusion instrumental variable model is given by

$$\ln \mathcal{L} = \sum_{j,\, \phi_j = 0} \left(\text{LYSINE}_j \gamma_{\text{LYSINE}} + \hat{\omega}_j \gamma_{\omega} + \mathbf{x}_j' \gamma_{\mathbf{x}} \right) + \sum_{j,\, \phi_j = 1} \left(\gamma_0 + \text{LYSINE}_j \gamma_{\text{LYSINE}} + \mathbf{x}_j' \gamma_{\mathbf{x}} \right)$$

$$- \sum_j \ln \left[\sum_{\tau \in R_j} \left(\exp\left(\text{LYSINE}_\tau \gamma_{\text{LYSINE}} + \mathbf{x}_\tau' \gamma_{\mathbf{x}} \right) + \exp\left(\gamma_0 + \text{LYSINE}_\tau \gamma_{\text{LYSINE}} + \mathbf{x}_\tau' \gamma_{\mathbf{x}} \right) \right) \right]$$

where γ_0 is a constant so that the baseline hazard functions for different types of cartel dissolution differ by a constant ratio.

I favor this nonlinear 2SRI approach for two reasons: First, it is appropriate given the data structure (Terza, Bradford and Dismuke 2008). Second, it yields consistent estimator of the effect of the LSP. Moreover, Terza (2006) shows that for models like equation (6) in which observable (i.e., LYSINE, $\mathbf{x}$) and unobservable (i.e., ω) regressors are given symmetric treatment in the specification, alternative estimators like the generalized method of moments are difficult to implement.

5.2. *Determinants of the LSP*

Table 4 provides evidence in support of the hypothesis that a cartel's decision to use the LSP was determined, at least in part, by linguistic differences. The first-stage relationship between linguistic differences and the LSP is strongly negative: the number of a cartel's languages is significantly related to the incidence of the LSP at over 90 percent confidence (regression (1) in Table 4), and this relationship is robust to the inclusion of controls for the effects of macroeconomic fluctuations (regression (2) in Table 4), antitrust policies (regression (3) in Table 4) and the other cartel organizational features (regression (4) in Table 4). Column (5) includes all the exogenous covariates, but excludes the other organizational features that are potentially exogenous. Column (6) relates all the explanatory variables in this table to the incidence of the LSP and confirms the results in columns (1)-(5). Together, these covariates explain from 32 to 48 percent of the differences in cartels' choice regarding the use of the LSP.

I experimented with a variety of other instrumental variables, including a categorical variable indicting the number of different languages spoken by the cartel members, a quadratic term for the number of languages, the number of different language families (e.g., Italic, Germanic, Slavic, Baltic, Arabic, east Asian, etc.) of the cartel members, and the number of countries where the cartel members are located. In the first two cases, the coefficient estimates are negative as expected and sometimes marginally statistically significant (regressions not shown). However, the first-stage results in these cases are weaker than the specifications presented in Table 4 (results not shown), so I opt for the more parsimonious specification above.

5.3. *The LSP and Cartel Duration: Main Empirical Result*

Panel A of Table 5 reports 2SRI estimates of the coefficients of interest. Panel B gives the corresponding first stages, with the other control variables indicated in that column (full results not reported to save space).[18] The residuals $\hat{\omega}$'s on the use of the LSP derived from equation (5) are positive and highly significant across all the specifications, which is indicative of endogeneity bias in the findings from the simple hazard models shown in Table 3.

An instrumental variable estimate including market structure controls yields point estimates of -2.88 (robust standard error 1.45) on cartel dissolution hazard, which is significant at 95 percent confidence (column (1) in Table 5). The point estimate indicates that using the LSP decreases (resp. increases) the dissolution hazard (resp. expected cartel duration) by 16.8 times

[18] See Table 4 for the full results.

Table 4. Determinants of The Use of The Lysine Strategy Profile (First-Stage)

	Dependent Variable Is LYSINE					
	(1)	(2)	(3)	(4)	(5)	(6)
LANG	−0.32*	−0.30*	−0.33*	−0.45**	−0.32*	−0.45**
	(0.17)	(0.17)	(0.17)	(0.22)	(0.17)	(0.21)
Log(FIRMS)	0.17**	0.26***	0.20**	0.22**	0.21**	0.21*
	(0.08)	(0.10)	(0.08)	(0.10)	(0.10)	(0.11)
Food, feed & tobacco	−0.22	−0.30	−0.13	−0.46	−0.37	−0.51
	(0.87)	(0.90)	(0.84)	(0.87)	(0.87)	(1.02)
Primary material	0.78	0.84	0.90	0.29	1.31	0.98
	(0.83)	(0.89)	(0.81)	(0.83)	(0.98)	(1.14)
Chemicals	1.27	1.26	1.36*	0.97	1.49	1.40
	(0.82)	(0.87)	(0.80)	(0.81)	(0.93)	(1.05)
Machinery, equipment &	0.50	0.64	0.60	0.27	0.89	0.76
metal products	(0.83)	(0.87)	(0.81)	(0.84)	(0.92)	(1.07)
Transport	−1.37	−1.50	−1.29	−1.65*	−1.57	−1.63
	(0.89)	(0.97)	(0.88)	(0.94)	(0.98)	(1.10)
Other products & services	−1.24	−1.50*	−1.21	−1.48	−1.20	−1.22
	(0.89)	(0.89)	(0.88)	(0.91)	(0.91)	(1.01)
Multinational	0.23	0.18	0.21	−0.34	−0.10	−0.67
	(0.49)	(0.52)	(0.50)	(0.57)	(0.58)	(0.65)
EEA-wide or EU-wide	0.00	0.27	−0.06	−0.23	0.12	−0.17
	(0.36)	(0.47)	(0.36)	(0.41)	(0.48)	(0.52)
Worldwide	0.94*	1.37*	0.87*	0.61	0.75	0.43
	(0.46)	(0.73)	(0.45)	(0.53)	(0.81)	(0.80)
Log(INTEREST)		−0.45*			−1.72***	−1.51**
		(0.26)			(0.64)	(0.70)
Log(PEAK-TROUGH+1)		−0.62			−0.52	−0.46
		(0.47)			(0.48)	(0.49)
Log(Δ GDP+2)		−0.10			−0.29	−0.46**
		(0.19)			(0.18)	(0.20)
Log(POS-SHOCK)		−0.18			−0.09	−0.05
		(0.12)			(0.12)	(0.13)
Log(NEG-SHOCK)		−0.21*			−0.15	−0.12
		(0.12)			(0.12)	(0.13)
EC's 1996 Leniency			0.28		−0.90*	−0.76
			(0.32)		(0.54)	(0.54)
EC's 2002 Leniency			0.11		−1.32*	−0.87
			(0.45)		(0.74)	(0.80)
Log(FINES)			0.00		−0.07	−0.08
			(0.06)		(0.07)	(0.08)
MARKET-ALLOC				1.25***		1.35***
				(0.38)		(0.37)
RETALIATION				0.59		0.53
				(0.37)		(0.34)
TRADE-ASSO				−0.04		0.04
				(0.33)		(0.32)

(*continued overleaf*)

TABLE 4. (*Continued*)

	Dependent Variable Is LYSINE					
	(1)	(2)	(3)	(4)	(5)	(6)
MARKET-LDR				0.69**		0.63**
				(0.28)		(0.31)
Constant	−0.93	1.68	−1.12	−1.97**	4.21**	2.48
	(0.78)	(1.46)	(0.80)	(0.81)	(1.69)	(1.93)
Observations	135	135	135	135	135	135
Pseudo R^2	0.32	-0.36	0.32	0.43	0.39	0.48

NOTE.– All regressions are probit. Dependent variable is the incidence of the lysine strategy profile. Robust standard errors are in parentheses. All euro values are in 2010 €. Omitted LENIENCY category is "no leniency". Omitted industry category is "wholesale and retail trade". Omitted market scope category is "national market". The source for these values is author's calculations based on 135 cartel decisions by the EC between 1980 and April 2011. *** significant at 1 percent level. ** significant at 5 percent level. * significant at 10 percent level.

$(\exp\{2.88\} - 1 \approx 16.8)$.[19] This estimate is larger in absolute value than the corresponding "naïve" Cox hazard model estimate (0.03). This suggests that ignoring the endogeneity of the LSP produces biased estimate of the its impact on duration.

The 2SRI estimate with additional controls for macroeconomic fluctuations is similarly large, negative, and significant at -3.69 (robust standard error 1.52 in column (2)). The effect of the LSP is robust to the inclusion of additional controls for antitrust policies (column (3) in Table 5) although the estimate is only marginally significant at 90 percent confidence.

Column (4) shows that adding the other cartel organizational features does not change the relationship: the LSP coefficient is now -2.41 with robust standard error of 1.16. Since I have instrumented for the LSP, I make the causal assertion that the duration of cartels that are discovered by the EC is influenced by the LSP, whereas a range of other cartel organizational features, such as retaliatory measures and market-leader arrangement, have, at best, a tenuous impact.

The magnitude of the estimated impact of the LSP on cartel dissolution hazard is large: when we look at the 2SRI specification with controls for market and macroeconomic conditions (column (2) in Table 5), for instance, the point estimate indicates that using the LSP decreases the dissolution hazard by 39 times $(\exp\{3.69\} - 1 \approx 39)$. Thus the LSP leads to a decrease in

[19] Let $f_i(t; \text{LYSINE}_i, \mathbf{x}_i, \hat{\omega}_i)$ denote the density function of the elapsed time since the start of cartel i. It can be shown that the expected cartel duration $\int f_i(t; \text{LYSINE}_i, \mathbf{x}_i, \hat{\omega}_i) t dt$ is given by $H_0(t)^{-1}[-\ln(1 - \exp(-H_0(t) \times \exp(\text{LYSINE}_i \gamma_{\text{LYSINE}} + \mathbf{x}_i'\gamma_{\mathbf{x}} + \hat{\omega}_i\gamma_\omega))) \exp(\text{LYSINE}_i \gamma_{\text{LYSINE}} + \mathbf{x}_i'\gamma_{\mathbf{x}} + \hat{\omega}_i\gamma_\omega)]$ where $H_0(t) = \int_0^t h_0(u)du$ is the cumulative baseline hazard function. It follows that $\int f_i(t; 1, \mathbf{x}_i, \hat{\omega}_i) t dt = \gamma_{\text{LYSINE}} \int f_i(t; 0, \mathbf{x}_i, \hat{\omega}_i) t dt$.

Table 5. The Lysine Strategy Profile and Cartel Duration (2SRI IV Regressions)

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Two-Stage Residual Inclusion Instrumental Variable Results						
	Dependent Variable Is Log(DURATION +1)					
LYSINE	−2.88**	−3.69**	−2.76*	−2.41**	−3.34**	−2.13*
	(1.45)	(1.52)	(1.50)	(1.16)	(1.45)	(1.23)
Residuals ($\hat{\omega}$) from 1st Stage†	2.91**	3.83**	2.81*	2.27**	3.41**	2.04*
	(1.44)	(1.52)	(1.48)	(1.11)	(1.42)	(1.17)
Log(FIRMS)	−0.20	−0.16	−0.21	−0.32**	−0.24*	−0.37**
	(0.14)	(0.14)	(0.15)	(0.15)	(0.14)	(0.16)
Food, feed & tobacco	−1.30*	−1.82**	−1.37*	−1.51*	−1.97**	−2.33**
	(0.72)	(0.74)	(0.77)	(0.84)	(0.87)	(1.02)
Primary material	−0.11	−0.21	−0.17	−0.82	0.50	−1.07
	(0.77)	(0.73)	(0.82)	(0.89)	(0.83)	(1.06)
Chemicals	0.35	0.38	0.28	−0.30	0.53	−0.88
	(0.84)	(0.90)	(0.93)	(0.86)	(0.93)	(1.14)
Machinery, equipment &	−0.64	−0.74	−0.71	−0.93	−0.54	−1.53
metal products	(0.67)	(0.73)	(0.74)	(0.83)	(0.80)	(1.02)
Transport	−2.15**	−2.42***	−2.19**	−1.86*	−2.28**	−2.29**
	(0.96)	(0.90)	(0.98)	(1.02)	(1.00)	(1.12)
Other products & services	−1.53*	−2.13**	−1.50*	−1.37	−1.78**	−1.89**
	(0.85)	(0.87)	(0.85)	(0.86)	(0.81)	(0.89)
Multinational	0.46	0.45	0.55	0.02	0.13	−0.03
	(0.73)	(0.68)	(0.73)	(0.69)	(0.73)	(0.78)
EEA-wide or EU-wide	0.21	0.54	0.25	−0.05	0.03	−0.11
	(0.46)	(0.51)	(0.46)	(0.48)	(0.55)	(0.59)
Worldwide	1.23**	1.74**	1.19**	0.85*	0.40	0.41
	(0.61)	(0.81)	(0.60)	(0.49)	(0.81)	(0.88)
Log(INTEREST)		−0.12			−1.76	−0.45
		(0.33)			(1.19)	(1.02)
Log(PEAK-TROUGH+1)		−0.20			0.11	−0.17
		(0.42)			(0.39)	(0.42)
Log(Δ GDP+2)		−0.56***			−0.79**	−0.78***
		(0.21)			(0.24)	(0.27)
Log(POS-SHOCK)		−0.25*			−0.05	−0.02
		(0.14)			(0.14)	(0.15)
Log(NEG-SHOCK)		−0.21			−0.02	0.04
		(0.14)			(0.16)	(0.16)
EC's 1996 Leniency			−0.15		−1.16	−0.41
			(0.30)		(0.80)	(0.75)
EC's 2002 Leniency			−0.35		−2.68**	−1.41
			(0.46)		(1.14)	(1.02)
Log(FINES)			0.02		0.04	0.06
			(0.05)		(0.08)	(0.08)
MARKET-ALLOC				−0.05		−0.14
				(0.53)		(0.59)

(*continued overleaf*)

TABLE 5. (*Continued*)

	Dependent Variable Is Log(DURATION +1)					
	(1)	(2)	(3)	(4)	(5)	(6)
RETALIATION				0.57*		0.65*
				(0.32)		(0.34)
TRADE-ASSO				−0.09		−0.18
				(0.28)		(0.38)
MARKET-LDR				1.22***		1.10***
				(0.39)		(0.39)
Number of failures	72	72	72	72	72	72
Time at risk	571.003	571.003	571.003	571.003	571.003	571.003
Log-pseudo likelihood	-283.42	-275.91	-282.89	-277.01	-273.92	-269.32

Panel B: First Stage for the Incidence of the LSP

	Dependent Variable Is LYSINE					
LANG	−0.32*	−0.30*	−0.33*	−0.45**	−0.32*	−0.45**
	(0.17)	(0.17)	(0.17)	(0.22)	(0.17)	(0.21)
Pseudo R^2	0.32	-0.36	0.32	0.43	0.39	0.48

Panel C: "Naïve" Cox Proportional Hazard Model Results

	Dependent Variable Is Log(DURATION +1)					
LYSINE	0.03	0.11	0.05	-0.18	0.06	-0.14
	(0.27)	(0.29)	(0.28)	(0.30)	(0.31)	(0.37)
Observations	135	135	135	135	135	135

NOTE.– Dependent variable is the Log DURATION + 1. Panel A reports the two-stage residual inclusion estimates, instrumented for the incidence of the LSP using Log LANG. The estimates correspond to the first-stage estimates in Table 4. Panel B reports the corresponding first stages, with the other control variables indicated in that column (full results not reported to save space). Panel C reports the Cox proportional hazard model with competing risks regression of the dependent variable against LYSINE, with the other control variables indicated in that column (full results not reported to save space). Robust standard errors are in parentheses. All euro values are in 2010 €. Omitted LENIENCY category is "no leniency". Omitted industry category is "wholesale and retail trade". Omitted market scope category is "national market". The source for these values is author's calculations based on 135 cartel decisions by the EC between 1980 and April 2011. *** significant at 1 percent level. ** significant at 5 percent level. * significant at 10 percent level. †The residuals represent the difference between cartels' actual use of the LSP and predicted use of the LSP from equation (5).

dissolution hazard that is greater than a six-percentage-point decline in demand growth does ($3.69/0.56 \approx 6.6$).

Column (5) includes all the exogenous variables in this table, but excludes organizational features other than the LSP. The estimated effect of the LSP remains negative, statistically significant and large in absolute value. Finally, in column (6), I relate all the explanatory variables in this table to the dissolution hazard and confirm the results in columns (1)-(5). The 2SRI coefficient is -2.13 instead of -3.34 as in column (5). This shows the exogenous characteristics do not fully capture all the factors that influence both a cartel decision to

use the LSP and cartel duration; But whether I use the other organizational features has no qualitative effect on my main result: The LSP prolongs cartel duration. Overall, the results in Table 5 show a large effect of the LSP on cartel duration. In the rest of the paper, I investigate the robustness of these results.

6. Robustness

6.1. *Test for the Direct Effect of Linguistic Difference on Duration*

The validity of my 2SRI results in Table 5 depends on the assumption that cartel members' linguistic differences display no direct effect on cartel duration. Although this presumption appears reasonable (at least to me), here I substantiate it further by directly controlling for some of the variables that could plausibly be correlated with both linguistic differences and cartel duration, and checking whether the addition of these variables affects my estimates.[20] Overall, I find that my results change remarkable little with the inclusion of these variables.

Firms' geographical dispersion and cultural diversity may also affect cartel duration (Zimmerman and Connor 2005).[21] To control for this, in columns (1) of Table 6, I add the number of (different) nationalities of cartel members. In column (2) of Table 6, I add a dummy for Asian-European cartel (cartels without an Asian firm colluding with an European firm are the omitted group) and a dummy for Continental European-Anglo-Saxon cartel (one if a continental European firm was colluding with a British, Irish, American or Canadian firm; zero otherwise).[22] Both the relationship between linguistic differences and the incidence of the LSP and that between the strategy profile and cartel duration are robust to the inclusion of the geographical dispersion and cultural differences variables. Finally, column (3) adds all the variables in columns (1) and (2) simultaneously. Again, these controls have very little effect on my main estimate.

[20] Altonji *et al.* (2000) propose an econometric methodology to assess the importance of omitted variable bias. The basic idea is that if the coefficient does not change as additional covariates are added in the regression equation, then the estimate of the coefficient of interest is less likely to change if we were able to include some of the missing omitted variables. My approach here is an informal version of this methodology.

[21] Zimmerman and Connor provide empirical evidence that increased geographic dispersion and cultural diversity among cartel members results in shorter cartel duration.

[22] All the cartels in the full cartel sample that involved collusion between American and Asian firms also involved European firms.

TABLE 6. ROBUSTNESS CHECKS FOR 2SRI IV REGRESSIONS OF LOG DURATION+1

	(1)	(2)	(3)	(4)	(5)
	Panel A: Two-Stage Residual Inclusion Instrumental Variable Results				
LYSINE	−1.86*	−2.38*	−2.08*	−2.43***	−8.22***
	(1.12)	(1.36)	(1.14)	(0.95)	(1.79)
Residuals ($\hat{\omega}$) from 1st Stage†	1.77*	2.36*	2.06*	2.39***	8.22***
	(1.09)	(1.31)	(1.14)	(0.92)	(1.78)
Log(COUNTRIES)	−0.08		−0.09		
	(0.35)		(0.35)		
ASIAN		0.17	0.12		
		(0.46)	(0.45)		
ANGLO-SAXON		−0.36	−0.32		
		(0.38)	(0.36)		
Log(FIRMS)	−0.37**	−0.36**	−0.36**	−0.39**	0.08
	(0.17)	(0.16)	(0.17)	(0.16)	(0.30)
Food, feed & tobacco	−2.33**	−2.42**	−2.40**	−2.37**	−2.30
	(1.02)	(1.12)	(1.06)	(1.04)	(1.67)
Primary material	−1.14	−1.07	−1.12	−0.90	2.59
	(1.04)	(1.16)	(1.07)	(0.96)	(1.87)
Chemicals	−1.05	−0.64	−0.82	−0.84	3.60**
	(1.09)	(1.27)	(1.15)	(0.92)	(1.69)
Machinery, equipment &	−1.61	−1.41	−1.51	−1.47	2.01
metal products	(0.97)	(1.10)	(1.00)	(0.90)	(1.83)
Transport	−2.26**	−2.30**	−2.26**	−2.67**	−3.91**
	(1.03)	(1.17)	(1.04)	(1.14)	(1.91)
Other products & services	−1.85**	−1.92**	−1.87**	−2.27**	−2.24
	(0.88)	(0.96)	(0.90)	(0.90)	(2.04)
Multinational	0.03	−0.05	0.01	−0.13	−2.59**
	(0.66)	(0.81)	(0.66)	(0.68)	(1.03)
EEA-wide or EU-wide	−0.04	−0.17	−0.08	−0.13	−2.43**
	(0.62)	(0.61)	(0.62)	(0.59)	(0.95)
Worldwide	0.43	0.37	0.38	0.48	−1.40
	(0.76)	(0.84)	(0.75)	(0.89)	(1.04)
Log(INTEREST)	−0.38	−0.43	−0.37	−0.75	−4.06***
	(0.76)	(1.04)	(0.75)	(0.89)	(1.32)
Log(PEAK-TROUGH+1)	−0.17	0.00	−0.02	−0.18	−0.94
	(0.48)	(0.45)	(0.48)	(0.44)	(0.70)
Log(Δ GDP+2)	−0.74***	−0.80***	−0.75***	−0.91***	−1.87**
	(0.26)	(0.27)	(0.26)	(0.22)	(0.75)
POS-SHOCK	−0.01	−0.01	0.00	−0.01	0.35
	(0.14)	(0.14)	(0.13)	(0.16)	(0.23)
NEG-SHOCK	0.05	0.05	0.06	0.04	0.33
	(0.14)	(0.15)	(0.14)	(0.17)	(0.25)
EC's 1996 Leniency	−0.35	−0.31	−0.27	−0.53	−2.44**
	(0.61)	(0.71)	(0.58)	(0.72)	(1.07)
EC's 2002 Leniency	−1.37	−1.36	−1.32	−1.55	−4.13***
	(0.87)	(1.04)	(0.87)	(1.02)	(1.32)

(*continued overleaf*)

TABLE 5. (*Continued*)

	(1)	(2)	(3)	(4)	(5)
	Panel A: Two-Stage Residual Inclusion Instrumental Variable Results				
Log(FINES)	0.07	0.06	0.07	0.05	−0.09
	(0.07)	(0.08)	(0.08)	(0.07)	(0.10)
MARKET-ALLOCATION	−0.18	0.01	−0.04	−0.09	2.71***
	(0.53)	(0.70)	(0.57)	(0.44)	(1.04)
RETALIATION	0.65*	0.78**	0.77**	0.63*	0.82
	(0.33)	(0.37)	(0.36)	(0.35)	(0.56)
TRADE-ASSOCIATION	−0.23	−0.16	−0.23	−0.12	0.89**
	(0.33)	(0.40)	(0.34)	(0.35)	(0.44)
MARKET-LDR	1.08***	1.05**	1.04***	1.11***	2.56***
	(0.39)	(0.37)	(0.37)	(0.36)	(0.59)
Number of failures	72	72	72	72	74.56
Time at risk	571.003	571.003	571.003	571.003	497.98
Log-pseudo likelihood	-269.67	-269.72	-269.31	-267.70	-321.35
	Panel B: First Stage for the Incidence of the LSP				
LANG	−0.47**	−0.55*	−0.60*	−0.45**	−0.45**
	(0.21)	(0.32)	(0.32)	(0.21)	(0.21)
Log(COUNTRIES)	−0.43		−0.47		
	(0.33)		(0.33)		
ASIAN		0.96*	0.98*		
		(0.55)	(0.57)		
ANGLO-SAXON		−0.14	−0.13		
		(0.43)	(0.43)		
Pseudo R^2	0.49	0.50	0.50	0.48	0.48
	Panel C: Simple Cox Proportional Hazard with Competing Risks				
LYSINE	−0.14	−0.13	−0.13	−0.13	0.10
	(0.37)	(0.38)	(0.38)	(0.34)	(0.45)
Log-pseudo likelihood	-271.02	-271.00	-271.00	-270.24	-334.58
Observations	135	135	135	135	135

NOTE.– Panel A reports the two-stage residual inclusion estimates with Log DURATION + 1 as dependent variable for regressions (1), (2), (3) and (5) and Log DURATION-2 + 1 as dependent variable for regression (4). Panel B reports the corresponding first stage, with the other control variables indicated in that column (full results not reported to save space). Panel C reports the estimates from Cox proportional hazard model with competing risks without instrumenting for the incidence of the LSP, with the other control variables indicated in that column (full results not reported to save space). Robust standard errors are in parentheses. All euro values are in 2010 €. Omitted LENIENCY category is "no leniency". Omitted industry category is "wholesale and retail trade". Omitted market scope category is "national market". ASIAN= 1 if one or more Asian firms are colluding with one or more European firms; 0 otherwise. ANGLO-SAXON= 1 if one or more continental European firms are colluding with one or more American, British, Irish or Canadian firms; 0 otherwise. The source for these values is author's calculations based on 135 cartel decisions by the EC between 1980 and April 2011. *** significant at 1 percent level. ** significant at 5 percent level. * significant at 10 percent level. †The residuals represent the difference between cartels' actual use of the LSP and predicted use of the LSP from equation (5).

6.2. *Alternative Cartel Duration Measure*

An antitrust authority may not want to jeopardize its case by aiming to prove what it thinks is the correct start date of collusion. Instead, it may aim for an outcome that inflicts adequate punishment and results in a conviction.[23] Therefore, the authority may not pursue an aggressive conviction strategy with regards to proving long infringement duration. As a second robustness check, I test whether my results are robust to alternative measure of cartel duration. I rerun the specification in column (6) of Table 5 but measure the speed of cartel dissolution by DURATION-2— the lengths of cartels' lifetime that are suspected by the EC but not necessarily with supporting document evidence. The coefficients in the first column of Table 6 (specification (4)) show that my results are robust to alternative definition of cartel duration.

6.3. *Non-Random Sample Selection*

Given that so far I have only examined detected cartels, my analysis may be subject to a selection-bias problem: As Posner (1970) and several others note (e.g., Taylor 2007; Harrington and Chang 2009; Miller 2009), one cannot be sure whether these are samples of firms and industries that were collusion prone or detection prone. This concern is addressed formally below, using propensity score reweighting techniques (Rosenbaum and Rubin 1983).

While one does not observe the criteria that a cartel uses to decide whether to use the LSP, the reweighting procedure reconstructs this information using observable characteristics. The procedure has two stages: In the first stage, I run the same probit model as I did in equation (5) using LYSINE as the dependent variable. The predicted probability from the probit model is an estimate of the propensity score; In the next stage, I use the first stage propensity scores as weights in a Cox proportional-hazard regression with competing risks using DURATION as the dependent variable with LYSINE and the other characteristics as covariates. The resulting weighted Cox proportional-hazard regression gives more weight to cartels without the LSP with larger estimated probabilities of using the LSP.

Column (5) of Table 6 documents that the propensity score adjustment does not alter my qualitative conclusions, which hold whether I weight or not. But the size of the LSP's stabilizing impact becomes unexpectedly large. This suggests the LSP is more effective at sustaining collusion in the sample of undetected cartels than in the sample of detected ones.

[23]This point is due to the insightful comment of George Deltas.

8. Conclusion

This paper addresses a major methodological issue that lies at the core of the cross-industry empirical literature on cartel durability— the potential endogeneity of the choices of cartels' organization used as explanatory variables. The causal effect on cartel duration of a particular and often observed organization—the LSP—is examined. Using a two-stage residual inclusion method (Terza, Basu and Rathouz 2008), I find that the LSP has a dramatic causal impact on cartel duration: cartels that use the strategy profile live longer than cartels without such a machinery. The impact is statistically significant, large in magnitude, and robust to various specification and sample choices, suggesting that the LSP is a powerful instrument for stabilizing a cartel.

My argument rests on the following premises: Inter-firm communication with the purposes of monitoring cheating forms the cornerstone of the LSP. Determinants of whether cartel members could easily communicate with each other, therefore, have an important effect on the cartel's ability to use the LSP. A cartel's decision regarding whether to use the LSP was in part determined by the existence and extent of linguistic barriers between the cartel members. I exploit these linguistic barriers— measured by the number of different national languages of a cartel— as a source of exogenous variation to estimate the impact of the LSP on cartel duration.

It is useful to point out that my findings do not imply that a cartel's decision regarding whether to use the LSP is determined by its members' linguistic divides. I emphasize linguistic differences as one of the many factors affecting the decision. Since linguistic barriers faced by cartels are arguably exogenous, they are useful as an instrument to isolate the effect of cartel organizational mechanism on cartel durability. In fact, my reading is that it may be possible to detect and destabilize cartels through focusing investigatory effort in industries in which price and sales are private information but the firms have little or no linguistic differences.

There are many questions that my analysis does not address. The LSP is treated largely as a "black box": The results indicate that preventing a cartel from using the LSP would destabilize the cartel, but do not point out what concrete steps an antitrust authority would take to distinguish usual, or sometimes welfare enhancing, information flows and inter-firm sales from the ones that are intended to monitor and penalize deviation. Cartels' organizational features, such as the LSP, should probably be interpreted as an equilibrium outcome (Harrington and Skrzypacz 2011), an optimizing behavior of the colluding firms in informational scarce environment and under the radar of antitrust detection. A more detailed empirical analysis of the

inner working of the LSP is an important area for future study.

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